Evaluation of Greenhouse Gas Benefits for Renewable Energy Technologies

Introduction

This white paper discusses whether the megawatt-hour (MWh) basis used by the Renewable Portfolio Standard (RPS) can be used for the Renewable Electricity Standard (RES) as a surrogate for determining greenhouse gas (GHG) reductions. Staff will perform this evaluation based on the GHG benefits expected from RES-eligible renewable energy technologies. If the results of this analysis show that the GHG benefits are similar for most renewable technologies, then MWh can be used as the basis for compliance with the RES.

Methodology

The GHG benefit for each technology is based upon the "net" GHG emissions from the renewable generator technology, GHG emissions from the operation of the energy technology, and GHG emissions associated with the incremental displacement of fossil fuel generation from the grid by renewable energy. The focus of this assessment is to determine the direct emissions from the renewable resource. It is not the intent to conduct a lifecycle analysis for each renewable generator technology. Because this review considers the benefits provided by displacing one MWh of power from the grid with renewable energy, a capacity factor is not included in determining the GHG benefit for each renewable technology.

The net GHG emissions are the difference between the GHG emissions from using the renewable resource in an energy technology, such as an internal combustion engine (engine) generator, and from the typical use or disposal of the renewable resource. Some technologies utilizing certain renewable resources do not emit GHGs; therefore, the net GHG emissions for these technologies are zero. In the case where biomass is combusted directly to generate electricity, staff assumed the GHG emissions would be the same if the biomass is allowed to decay in its natural environment or if the biomass is combusted in an energy device; consequently, the net GHG emissions are zero. For technologies where the renewable is converted to a fuel (for example, converting biomass to biodiesel), the GHG emissions associated with conversion are included in the net GHG determination. Because landfills emit both methane and carbon dioxide (CO_2), any technology that involves the use of landfill gas or municipal solid waste (MSW) must include the impact of converting methane to CO_2 when determining the net GHG emissions since methane is 21 times more potent as a GHG than CO_2. Finally, some technologies, such as geothermal power plants, may emit CO_2 that was part of the local geological features accessed by the geothermal facility.

Staff evaluated GHG emissions from material transport, operation and maintenance activities at eligible renewable technologies. Staff determined that, except for transportation used to deliver biomass fuel to biomass combustion plants, the GHG emissions related to transportation and operation and maintenance are minor.

The major benefit from using renewable power is the displacement of power produced by burning carbon-based fuels that would otherwise be used to meet the demand on the utility grid. The power being displaced is incremental power provided by generators to address load changes (“marginal power”), which is typically provided by natural gas power plants. With the integration of 33 percent renewable energy into the grid in 2020, the incremental power being displaced by renewable energy in 2020 is likely different than the incremental power that would be displaced by renewable energy today. That is, by 2020, the fossil fuel power plant fleet is expected to differ from today’s fleet in that older and less efficient power plants, mainly utility boilers, will be retired and new more efficient gas turbine combined cycle power plants will be added. Consequently, the GHG emissions associated with the incremental power generation will likely be lower in 2020. Staff is continuing to work with the California Independent System Operator (CAISO) to determine the GHG emissions associated with the marginal power. For this analysis, staff is using 1,100 lbs CO_2 equivalent (CO_2e) per MWh as an estimate of the GHG emissions associated with the marginal power. This value was developed by the CEC and is intended to be a GHG performance standard for new power plants that would be expected to come on-line if the RPS were not increased.

Results and Discussion

Table 1, GHG Benefit Determination for Renewable Sources, provides a summary of the GHG benefits for the renewable energy technologies eligible for the RPS. Overall, with the exception of MSW, the GHG benefits estimated for the renewable technologies range from 830 to 1,200 lb CO_2e per MWh. As discussed below the GHG benefits for MSW are highly variable, depending upon the amount and types of waste removed from MSW prior to the conversion process. Staff has determined this range to be -700 to 2,100 lb CO_2e per MWh. This range can be narrowed with additional information on the waste screening practices.

For many of the renewable resources or technologies, the GHG benefit is the GHG emissions associated with displacing natural gas generation. These include biogas injection, fuel cells using renewable fuels, hydropower, ocean technologies, solar, and wind. For this analysis, GHG emissions from backup generation that is used for wind and solar is not included for determining the benefits from solar and wind. Should CAISO’s forthcoming study for integrating 33 percent renewable energy show that additional backup power for intermittent technologies is necessary, over and above what is typically used by balancing authorities to backup the grid, staff will include the GHG emissions associated with the additional backup power in determining the GHG benefits.

For the purposes of this analysis, GHG benefits for biomass combustion, biomass to biodiesel conversion, and geothermal were reduced. For biomass combustion, GHG emissions from transportation were subtracted from the calculated benefits. GHG emissions from the conversion process were subtracted for biomass conversion. Finally, geothermal plants were discounted for operational emissions.

Municipal solid waste (MSW) landfills can be significant sources of methane and CO_2 emissions. In California, most landfills emitting significant amounts of gas are required by either federal programs (New Source Performance Standards (NSPS) or Emission Guidelines (EG)) or local district requirements to install landfill gas collection systems and satisfy a destruction efficiency of 98 percent for the volatile organic portion of the collected gas. The destruction efficiency can be satisfied with a flare or gas-to-energy system. With the exception of lean-burn engines, landfill gas-to-energy systems have the same destruction efficiency as a flare. Lean-burn engines do not incinerate the gas as well as a flare, resulting in a net increase of GHG emissions—considering that methane is 21 times more potent as a GHG than CO_2, the GHG benefit for a California landfill project is 430 lb CO_2e per MWh (1,100 lb CO_2e per MWh for the marginal power minus 670 lb CO_2e per MWh for the increased methane emissions).

Outside of California, generally only the largest landfills are subject to air quality requirements (via the federal NSPS or EG programs). Smaller landfills located outside California are typically not regulated. Landfill gas-to-energy systems installed at these landfills will result in a net reduction of GHG emissions—the GHG benefit for these unregulated landfill projects, including the conversion of methane to CO_2, is 1,800 lb CO_2e per MWh (1,100 lb CO_2e per MWh for the marginal power plus 670 lb CO_2e per MWh for the reduced methane emissions).

In summary, the GHG benefits for in-state landfill projects will be much lower than the benefits from out-of-state projects. Overall, staff expects more out-of-state landfill projects than in-state projects to contribute to RES compliance. Based on a split of 45 percent of MWh from California projects and 55 percent from out-of-state projects (based on candidate projects identified by the Landfill Methane Outreach Program (LMOP) located within the Western Electricity Coordinating Council (WECC)), the overall average benefit would be 1,200 lb CO_2 per MWh.

Similar to landfill gas application discussed above, the benefits for MSW conversion technologies (combustion, gasification, and pyrolysis) includes the reduction of methane emissions that would have otherwise been emitted if the waste was landfilled. The benefit for MSW conversion includes the GHG emissions for the electricity displaced from the grid, the GHG emissions from the conversion process, and the GHG emissions associated with the reduction in landfill gas emissions. The GHG emissions from the conversion process are affected by the amount and types of waste that can be segregated from the waste stream. Consequently, the conversion process emissions can vary from 1,500 to 4,300 lb CO_2e per MWh, with the lowest emission rate based on removing the maximum amount of renewable waste from MSW. Overall, the GHG benefit for a

MSW project can vary over a wide range: from -700 to 2,100 lb CO_2e per MWh (for the maximum sorting case, the estimate is based on the following: 1,100 lb CO_2e per MWh for the marginal power minus 1,500 lb CO_2e per MWh for the conversion of MSW to energy plus 2,500 lb CO_2e per MWh for the decrease in landfill gas emissions from the landfill).

Therefore, the GHG benefit for a MSW conversion project will be project-specific, depending upon the types of waste that are removed from the waste stream prior to the conversion process. For a MSW conversion project to be eligible for the RES, the applicable eligibility requirements for the RPS must be satisfied. This includes removing, as much as possible, "the recyclable materials and marketable green waste compostable materials from the solid waste stream before the conversion process"[1]. Based on these requirements, most MSW conversion projects will likely provide a GHG benefit.

The above discussion does not consider the expected quantities of generation provided by each resource or technology. The Public Utilities Commission has estimated[2] that wind and solar generation will likely provide 77 percent of the generation toward the 33 percent renewable goals. Additionally, the combination of wind, solar, and geothermal will provide over 90 percent of the total necessary generation. These three resources have a GHG benefit between 830 to 1,100 lb CO_2e per MWh.

Summary

Based on staff analysis, except for MSW conversion, the GHG benefits are similar between the various renewables—between 830 to 1,200 lb CO_2e per MWh. Because of the uncertainty regarding how much waste segregation will be used for a MSW conversion project, the GHG benefit for this technology cannot be determined on a general basis. Additionally, for the resources likely to provide the necessary generation to satisfy a 33 percent renewal goal, the GHG benefits fall within a fairly narrow range. Therefore, staff believes a MWh metric is an appropriate surrogate for estimating the GHG benefits for renewable resources.

[1] California Energy Commission, Renewables Portfolio Standard Eligibility, Third Edition, 2008
[2] Public Utilities Commission, 33% Renewables Portfolio Standard Implementation Analysis Preliminary Results, 2009

Table 1
GHG Benefit Determination
for Renewable Sources

Technology	**Potential GHG Benefit**[3] (lb CO_2e per MWh)	**Comments**
Biogas Injection	1,100	Benefit based on 100 percent use of biogas pipeline fuel—for existing projects using biogas injected in a natural gas line, the biogas represents a portion of fuel used by generator
Biomass Combustion	1,030	Includes GHG emissions from transportation[4]
Converting Biomass to Biodiesel	830	Includes GHG emissions from conversion of biomass to biodiesel[5]
Fuel cell	1,100	Using renewable fuel
Geothermal	850-1,000	GHG emissions resulting from operation—no emissions if heat stream is re-injected[6]

[3] Benefit is based on one MWh renewable generation.
[4] GHG emissions for transportation are based upon the operation data from the late 1990's for six California biomass-to-energy plants. The data includes the amount of biomass used by each plant and the GWh produced by each plant. Using this information and assuming each truck would carry 20 tons of biomass per trip and the truck would travel 80 miles roundtrip, staff estimated transportation GHG emissions as 70 lbs CO_2e per MWh.
[5] To estimate the energy needed to convert biomass into renewable diesel, staff evaluated the energy needed to use the Fischer-Tropsch (F-T) process to produce biodiesel. The F-T process is energy intensive, but in addition to producing biodiesel, electricity and naphtha are produced as co-benefits. Information on process take from Strategic Assessment of Bioenergy Development in the West. Task 2: Bioenergy Conversion Technology Characteristics, Antares Group, 2008. For the purposes of the GHG benefit analysis, the benefit was reduced by1,370 lbs CO_2e per MWh, but electricity co-benefit of 1,100 lbs CO_2e per MWh was added—a net reduction of 300 lbs CO_2e per MWh
[6] Based on range of emissions for several geothermal generators

Technology	Potential GHG Benefit	Comments
Hydropower and Conduit Hydropower	1,100	
Landfill/Digester	1,200	Includes increased methane reduction for out-of-state projects and increased emissions of methane for in-state projects; assumes that 55 percent of projects are out-of-state
Municipal Solid Waste	-700 to 2,100	Includes GHG emissions from conversion of MSW and benefit for conversion of methane; range dependent upon waste segregation
Ocean Technologies	1,100	
Solar	1,100	May need to add backup GHG emissions
Wind	1,100	May need to add backup GHG emissions